Berwick Bank Wind Farm

Additional Environmental Information (AEI) Submission

AEI03: Section 2 Supplementary Information Sufficiency and Immediate Benefit of the Sandeel Compensation Measures

sse Renewables

Revision Information					
Rev	Issue Status	Date	Originator	Checker	Approver
A01	Approved for use	03/08/2023	MacArthur Green	JA	SE

Approval for Issue		
Approver's name	SIGNATURE	DATE
Sarah Edwards		03/08/2023

Contents

Acronyms

Acronym	Description
AEI	Additional Environmental Information
CCM	Colony Compensation measures
EIA	Environmental Impact Assessment
EU	European Union
FCM	Fisheries Compensatory Measures
MD-LOT	Marine Scotland Licensing and Operations Team
NTS	National Trust for Scotland
PVA	Population Viability Analysis
PEMP	Project Environmental Monitoring Programme
RIAA	Report to Inform Appropriate Assessment
SNH	Scottish Natural Heritage
SWT	Scottish Wildlife Trust
SSB	Spawning Stock Biomass
SPA	Special Protection Area
SSER	SSE Renewables
SSG	Strategic Stakeholder Group
TAC	Total Allowable Catch
TSB	Total Stock Biomass
UK	United Kingdom
UKCEH	UK Centre for Ecology and Hydrology

Purpose of the Report

The purpose of this report is to provide evidence and additional analysis to address and allay concerns expressed by NatureScot concerning the timing of realisation of ecological benefits from the management of closures of the sandeel fishery and the potential impacts from the project.

1. Introduction

The report is structured as follows. Firstly, a summary of the evidence provided by the Applicant in the original submission is provided and an overview of the importance of the relationship between sandeels and seabirds is described. This well-established relationship is used to demonstrate, using highly precautionary assessments, that an increase of Total Stock Biomass (TSB) of the sandeel fishery will compensate for the predicted impacts from the project.

NatureScot agree that increasing sandeel availability would provide the best chance of increasing seabird populations likely to be affected by the project. However, concerns are expressed about the timing of the benefits and the impacts from the project. This part of the report shows NatureScot's comments and explains how the additional analyses will address and allay these concerns.

The next section of the report provides three discrete sets of analyses that significantly reduce the uncertainty expressed above on the timing of benefits. The first demonstrates that reduction/removal of fishing pressure and thus increase in TSB and its impact on adult survival alone is enough to immediately offset the impacts of the project. An intrinsic increase in the sandeel population and improvements in seabird productivity do not need to be relied on to offset impacts, although they will provide large benefits in the medium term.

This analysis is further developed by carrying out a hindcast analysis of the impact of the removal of fishing pressure and the impact on adult survival. This shows that the changes in Sandeel TSB required to compensate for impacts are well within historic norms of Sandeel TAC and that if the project had been built in 2017 and Sandeel Fisheries closed at the same time, then the benefits from this closure would have more than compensated for any impacts from the project. This analysis assumes that the benefit will only be derived from the benefit to adult survival.

Finally, a range of incremental changes in Sandeel TSB are assessed using a 10 year PVA to provide realistic absolute estimates of the changes in seabird populations resulting from a removal of fishing pressure. The PVA model and population demographics recommended in the Scoping Opinion are used to carry out this analysis. Again, this demonstrates that closure of the Sandeel Fishery is sufficient to offset the impacts of the project.

The report concludes by summarising the new evidence provided to make a robust and precautionary case that an increase in Sandeel TSB, via the management/closure of the sandeel fishery will provide an immediate benefit to the key seabird populations that will offset the impacts of the project and could provide compensation for other projects and improve the resilience of seabirds to future pressures.

2. Overview of the evidence provided in the original submission

This section provides an overview of the evidence and analysis that the Applicant submitted in the original derogation case. This demonstrates that, using a precautionary approach, an increase in Sandeel TSB, via the management/closure of the sandeel fishery will offset the impact of the project.

Fisheries can have important negative effects on fish stocks that many fish-eating seabirds depend upon. There are numerous examples of the benefits of improvements to fisheries management to the demography of breeding seabirds.

In the North Sea the sandeel (*Ammodytes* spp.) is a very important forage fish and a key species for the whole ecosystem. Current fisheries management of the sandeel stocks in the North Sea has resulted in depletion of these stocks below the level necessary for healthy fish-eating seabird populations.

Multiple studies have demonstrated the importance of sandeel stocks for breeding seabirds in the North Sea. Both productivity and adult survival of sandeel-dependent seabirds have been shown to be negatively affected by low sandeel availability.

Evidence of strong relationships between sandeel total stock biomass TSB in SA4 and population size, adult survival and productivity was presented in the Fisheries Compensatory Measures Evidence Report from seabird data collected by UKCEH on the Isle of May for kittiwake, guillemot, razorbill and puffin. For razorbill strong relationships were shown for population size and adult survival, though not for productivity.

Analyses also showed that there was a strong relationship between fishing effort and sandeel spawning stock biomass in SA4, suggesting that fishing effort negatively effects the sandeel stocks in SA4. In addition, previous modelling work has shown that removal or reduction in fishing pressure on sandeels in the North Sea would result in increases in sandeel populations. This is a pattern typically seen in other fisheries on other fish species around the world. The best available evidence shows that improvements to the management of the SA4 stock, or closure of SA4 to sandeel fishing, would provide demographic benefits to the key seabird species of relevance, and therefore could be used as a compensation measure for predicted impacts from the project.

The relationships between sandeel TSB and seabird demography from the Isle of May were used to predict the likely gains to seabirds from increasing the TSB in SA4. The additional number of birds per annum predicted from these relationships was compared with the predicted impacts on the relevant SPA populations from the project alone. Five compensation scenarios were used to show the range of potentially realistic changes as a result of the proposed compensation measures. The scenario that produced the smallest benefit was the change in sandeel TSB from 300,000 to 400,000 tonnes. The largest predicted change to SPA populations and demography was from the change in sandeel TSB from 100,000 to 200,000 tonnes. An example for kittiwake is shown inTable 1. The relationships for the other species that were assessed are available in the Fisheries Compensatory Measures Evidence Report.

Table 1 Scenarios showing the change in survival rate and productivity for kittiwakes for a range of changes in sandeel stock biomass in SA4

Scenarios	Increase in TSB	Survival rate increase	% increase in Adult Survival	Productivity rate increase	% increase in Productivity
100k to 200k	100k	0.75 to 0.82	8.4%	0.62 to 0.76	22.6%
200k to 300k	100k	0.82 to 0.85	4.5%	0.76 to 0.84	10.8%
300k to 400k	100k	0.85 to 0.88	3.1%	0.84 to 0.90	6.9%
300k to 600k	300k	0.85 to 0.91	7.4%	0.84 to 0.98	16.6%
300k to 800k	500k	0.85 to 0.94	10.5%	0.84 to 1.04	23.5%

The assessment was based on the potential benefits from the scenario that created the smallest demographic response from seabirds. This was compared with the largest potential impacts predicted from the project alone (Scope B). Therefore, the assessment was precautionary by comparing the lowest plausible benefit scenario from sandeel fisheries closure with the largest estimated impact scenario.

Further precaution was included through a variety of assumptions used in the analyses. The analyses did not include the benefits of the closure of SA4 to sandeel fisheries to seabird colonies not within the SPAs predicted to be impacted. Should SA4 be closed to sandeel fisheries it is highly likely that the wider population of each species would benefit, increasing the overall resilience of the total seabird population.

It was also assumed that the benefit from reduced fisheries on the SA4 sandeel population did not extend to those seabird colonies near the northern border of SA4 (southern Orkney and northern Caithness). There is more uncertainty in the potential benefits to colonies in this area, but it is possible that they would also benefit from increases in adult survival and productivity following closure of the fishery. Finally, due to a lack of empirical evidence it was assumed that the immature age classes (which are about one-third to half of the population of each species) would not benefit from closure of SA4 to sandeel fisheries. It is highly likely that this portion of the population would also see survival benefits from closure of the fishery, which would increase the number of immature birds available to recruit into the breeding adult population. Indeed, it is likely that immature survival may increase more than adult survival for birds present in the SA4 area if sandeel stock recovered, since immature birds are less competitive, so would be likely to be more strongly adversely affected by depletion of their food resource than are the more experienced adults.

In summary, the assessment of the benefits of sandeel fisheries closure was precautionary due to:

- Smallest realistic change in sandeel TSB used compared against the largest predicted impact from the Report to Inform Appropriate Assessment (RIAA);
- Assumption of closed seabird populations;
- Assumption that only SPA population will benefit; and
- Assumption that immature age classes will not benefit.

Across the range of likely changes in sandeel TSB in SA4, it was found that reducing or removing fishing pressure would have positive effects on adult survival for all species and productivity for all species other than razorbill, It was clear that the predicted minimum benefit to the key species from reducing or removing fishing pressure in SA4 was sufficient to compensate for all predicted impact scenarios, including the most precautionary (Scope B).

2.1. Stakeholder concerns

The overview of evidence above shows that closure of sandeel fisheries will offset the impacts of the project.

In their advice on the proposed compensation measure, NatureScot stated that,

"We agree that increasing sandeel availability would provide the best chance of increasing seabird populations likely to be affected by the proposed project, due to increased survival, or increased productivity and survival. However, there is substantial uncertainty around the timing of when benefits to seabirds from the proposed closure of SA4 would be delivered. This relates to the gap between cause and effect, linked to the age of sexual maturity of seabirds (between 4-6 years) and the associated delay to any increase in productivity, combined with the uncertainty associated with the timing of the recovery of sandeel biomass and ongoing predicted impacts to survival from the operation of the wind farm.

Given the unprecedented scale of predicted impacts to many vulnerable seabird populations, we are concerned that there could be substantial losses between commencement of operation and any compensatory benefits from the proposed measures being realised. Compensation benefits must therefore be in place before operational impacts occur, otherwise predicted losses during this lag could seriously

undermine the ability of the proposed measures to offset predicted impacts, throughout the lifespan of the wind farm."

These concerns centre on two key issues.

1. A possible delay in benefits to seabirds due to the time required for seabirds to reach sexual maturity (4-6 years, depending upon the species), which would mean that increases in the adult population from improvements in productivity would not start to occur for between 4 and 6 years.
2. Uncertainty associated with the recovery of the sandeel population. If sandeel populations do not recover as quickly as predicted, then the benefits to survival and productivity may not occur in time to offset the impacts of the project.

The assumption underpinning this concern is that the primary benefit to seabirds is via the mechanism of increased Sandeel Spawning Stock Biomass leading to an increase Sandeel TSB. This increase in TSB leads to a reduction in chick mortality which leads to an increase in immature birds, which after 4 to 6 years leads to more adult seabirds able to recruit into the SPA network. These adult seabirds are required to compensate for predicted impacts of the project. This mechanism can be seen as the process on the left-hand side of Figure 1.0 below.

However, there are other processes that drive an immediate improvement in the seabird population. This mechanism is shown in the right-hand side of Figure 1.0 below. The removal of fishing pressure from the sandeel fishery from closure, leads to an immediate increase in the Sandeel TSB. Given the established relationship between Sandeel TSB and Adult survival leads to an immediate increase in the number adults in the population.

The analyses below demonstrate that this mechanism alone is sufficient to immediately offset the impacts of the project. A brief overview of each analysis is provided below.

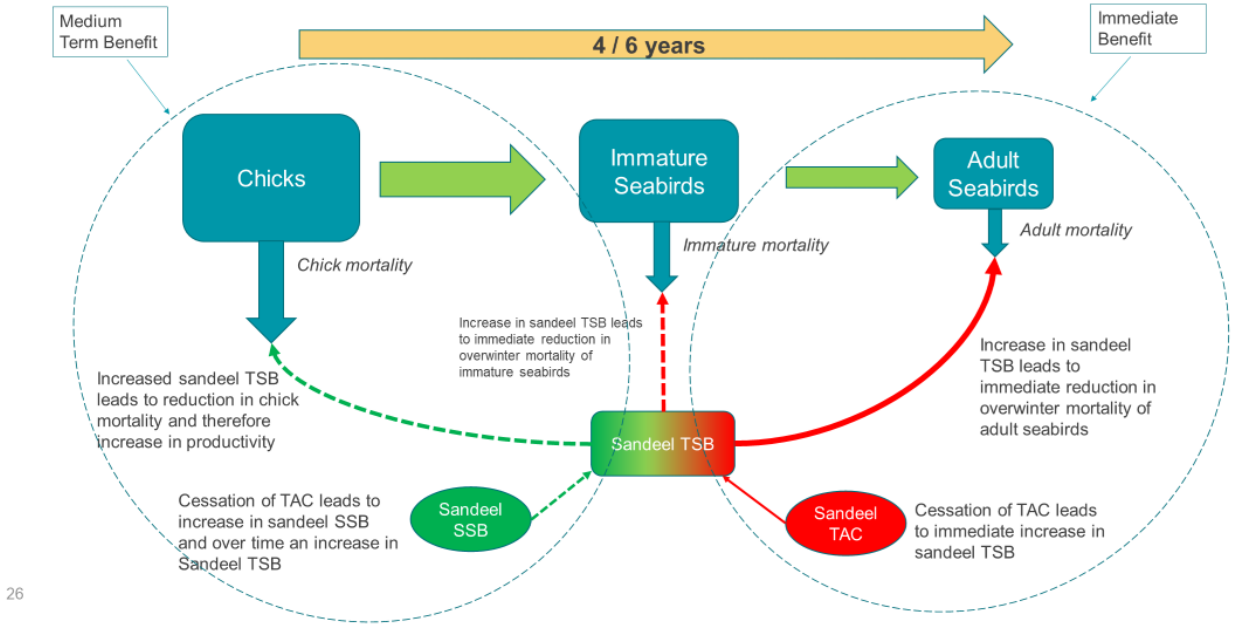

Figure 1 Immediate and medium-term benefit to seabird populations

Firstly, the closure of the sandeel fishery would result in an immediate increase in the survival of adult birds from the SPAs predicted to be impacted by a sufficient amount to fully compensate for the predicted annual impacts from the project alone. This can be demonstrated by considering the effects of benefits on adult

survival from changes in sandeel TSB in SA4 using various scenarios. Analyses were undertaken to show the effect of incremental increases in sandeel TSB in SA4 *between* 300,000 tonnes and 400,000 tonnes. While the increase in sandeel TSB from 300,000 tonnes to 400,000 tonnes is both plausible and is the sandeel TSB change scenario previously shown in the Fisheries Compensatory Measures Evidence Report to have the smallest benefit, there is some uncertainty in how long it may take the sandeel stock to increase by 100,000 tonnes, because recruitment in sandeels tends to be highly variable from year to year, and tends to be lower for severely depleted spawning stock biomass.

However, positive effects on sandeel TSB will occur immediately on closure of sandeel fishing. Such gains do not depend on recruitment alone. Simply the removal of fishing mortality will result in the sandeel stock biomass being higher than it would have been if fishing had continued to extract sandeels from the stock. Over the last six years the average catch of sandeels in SA4 was 24,349 tonnes (ICES 2023[1]), though with a very large range (6,651 to 53,081 tonnes). Therefore, to test whether the removal of fishing pressure leading to an increase in Sandeel TSB is sufficient to offset impacts incremental increases in sandeel TSB from 300,000 tonnes in 5% (15,000) increments to a 25% (75,000) increase were assessed. This analysis shows that only a 10% increase in Sandeel TSB is needed to offset the impacts on kittiwake and guillemot and a 5% increase for razorbill and puffin. This benefit is from an increase in adult survival only.

Secondly, a hindcast analysis was completed based on the predicted SA4 sandeel TSB and reported catch from ICES (2023). This predicted the number of additional adult birds that would have survived had each year's catch not been removed from the sandeel stock in SA4 between 2017 and 2022. This analysis shows that if the project had been built in 2017 and sandeel fisheries closed at the same time then there would have been a net increase in all key species. This analysis assumes that there is no benefit resulting from a recovery in the sandeel population and there is no increase in seabird productivity.

Finally, a PVA was run over a ten-year period, to test the population responses to increases in both survival and productivity (only survival for razorbill) from these smaller, incremental, increases in sandeel TSB. The analysis fully considers the time taken to reach sexual maturity and the impact on the timing of the benefit, which was one of NatureScot's key concerns. The outputs demonstrate that only a 5% increase in Sandeel TSB is needed to fully offset the impacts for all the key species.

From each of these analyses the immediate short-term net benefit to the overall SPA populations predicted to be impacted by the project were estimated so the concerns from NatureScot could be analysed. Note that in reality we can expect more than these immediate benefits, since we can expect gains due to recruitment from a less depleted spawning stock biomass as well as these immediate gains due to the prey density not being reduced within-year by fishing.

2.2. Calculated annual benefit of sandeel closure to breeding adults from survival effects

This analysis seeks to demonstrate that removal of TAC, similar to historic norms, would be sufficient to offset impacts via an increase in adult survival only. The analysis has three steps.

1. Calculate the increase in adult survival for a range of small increases in Sandeel TSB
2. Multiply by the adult population for each of SPAs potentially impacted
3. Compare the benefit generated against the worst case predicted impacts

Greater detail and explanation of this process and the outputs are shown below.

[1] ICES (2023) Herring assessment working group for the area south of 62ºN (HAWG). ICES Scientific Reports 5: 23

Using the relationship between sandeel TSB in SA4 and adult survival for each species that was shown in the Fisheries Compensatory Measures Evidence Report, the predicted adult survival across the six scenarios being tested (5% increase in TSB to increase in TSB to 400,000 tonnes) was calculated (Table 2). The increments chosen were based on the most recent estimate of the TSB (309,858 t) and TAC (35,020 t) from ICES (2023). This TAC is about 15% of a starting TSB of 300,000 tonnes, thus the change in TSB at two 5% increments on either side of this TSB (345,000 t) was tested to provide a wide range for context. The change to 400,000 tonnes was also included, as this was the lowest change in adult survival and productivity scenario tested in the Fisheries Compensatory Measures Evidence Report.

Table 2 Predicted increase in adult survival of all species from incremental increases in sandeel TSB in SA4

		Kittiwake		Guillemot		Razorbill		Puffin	
Scenario	Sandeel TSB	Predicted adult survival	Increase in adult survival	Predicted adult survival	Increase in adult survival	Predicted adult survival	Increase in adult survival	Predicted adult survival	Increase in adult survival
Baseline	300,000	0.852		0.9104		0.9006		0.8843	
5%	315,000	0.8564	0.0044	0.9131	0.0027	0.9028	0.0021	0.8891	0.0048
10%	330,000	0.8607	0.0087	0.9157	0.0053	0.9048	0.0041	0.8938	0.0095
15%	345,000	0.8647	0.0127	0.9181	0.0078	0.9067	0.0061	0.8982	0.0139
20%	360,000	0.8686	0.0166	0.9205	0.0102	0.9086	0.0079	0.9024	0.0181
25%	375,000	0.8723	0.0203	0.9228	0.0124	0.9103	0.0097	0.9065	0.0222
400, 000 tonnes	400,000	0.8781	0.0262	0.9264	0.016	0.9131	0.0125	0.9129	0.0286

The increase in adult survival could then be used to estimate the number of additional adults predicted to survive had the additional sandeel stock been available. Multiplying this increase in adult survival by the total breeding adult populations size of the SPAs (0-3) predicted to be impacted by the project provided the immediate benefit from each change in predicted sandeel TSB in SA4.

Table 3 Population sizes (individual breeding adults) across the SPAs predicted to be impacted by the project and the total population size used in the assessment.

SPA	Population size (individual breeding adults)			
	Kittiwake	Guillemot	Razorbill	Puffin
Forth Islands	9,034	34,580	7,878	87,240
St Abbs Head to Fast Castle	10,904	61,408	3,928	
Fowlsheugh	26,542	91,358	17,817	
Farne Islands	8,804			
East Caithness Cliffs	48,920		40,117	
Troup, Pennan & Lion's Heads	21,232	31,893		
Buchan Ness to Collieston Coast	22,590	39,553	6,054	
Farne Islands		85,816	572	87,504
Total	148,026	344,608	76,366	174,744

For each species the estimated annual predicted net benefit (predicted benefit minus the predicted impact) was calculated from closure of the sandeel fishery in SA4 for a range of additional sandeels available due to removal of TAC (Table 4). This approach excludes the increase in the total sandeel population from increased recruitment due to the removal of fishing pressure.

The calculation showed that there would be an immediate net benefit from increases in adult survival where the change in sandeel TSB from 300,000 tonnes was 10% (i.e. 330,000 tonnes) for kittiwake and guillemot and only 5% (i.e. 315,000 tonnes) for razorbill and puffin.

So, for each species the removal of the 2023 TAC would have been sufficient to compensate immediately for the predicted annual impacts from the project alone.

Table 4 Summary of calculated net benefit from closure of fishing and adult benefit only

Species	SPA Population size total (individual adults)	Net Benefit (5%)	Net Benefit (10%)	Net Benefit (15%)	Net Benefit (20%)	Net Benefit (25%)	Net Benefit (400,000 t)
Kittiwake	148,026	-4	622	1,220	1,792	2,342	3,210
Guillemot	344,608	-493	400	1,253	2,070	2,853	4,092
Razorbill	76,366	87	241	388	529	665	879
Puffin	174,744	814	1,622	2,394	3,133	3,843	4,964

The table above shows the net benefit to the SPA populations of the key species from five scenarios where the sandeel TSB increases in 5% increments from a baseline of 300,000 tonnes, and one scenario where the sandeel TSB increases to 400,000 tonnes. For example, if the sandeel TSB increases by 10% (30,000 tonnes) then there will be an immediate net benefit of 622 adult kittiwakes, 400 adult guillemots, 87 adult razorbills and 814 adult puffins. The TAC for SA4 in 2023 was 35,020 tonnes.

The response of the adult breeding population to even small increases in sandeel TSB above 300,000 tonnes is clear. It is important to note that this is only the immediate annual effect of increases in sandeel TSB in SA4 affecting adult survival. It is highly likely that these immediate changes would also directly affect the immature age classes of these populations, resulting in an immediate increase in birds available to recruit into the population for the oldest age class of immature birds. This was not calculated as there were no empirical data to inform the scale of the potential increase in immature survival. The assessment also does not account for any increases in seabird productivity, albeit with a delayed demographic response, rather than an immediate benefit. Finally, this assessment assumed that the sandeel population only benefits from the increased TSB as a result of the TAC not being taken, and not the likely demographic response from the sandeel population in SA4.

2.3. Six-year Hindcast of Net Benefit from Closure of Fishery and Adult Survival

The analyses presented above, and in the Fisheries Compensatory Measures Evidence Report, are based upon a combination of the available historical information on sandeel stocks in SA4 and the relationship between those stocks and seabird demographics. The approach was therefore to take a reasonable worst-

case benefit scenario (a change in sandeel TSB in SA4 from 300,000 tonnes to 400,000 tonnes) to inform the forward projection of populations size and growth across the duration of the windfarm operation. While this is a reasonable approach to forecasting the potential benefits from sandeel fisheries closure in SA4, an alternative is using past data to hindcast the potential response of seabird populations had sandeel fisheries been closed at some point in the past, based on actual data on catches and stock biomass each year. This approach helps to demonstrate that the scenario-based testing above and in the Fisheries Compensatory Measures Evidence Report are reasonable and likely to occur in the short-term following fisheries closure.

These analyses were based on the likely additional number of adult seabirds predicted to survive had the catch over the last six years not occurred. This time period covers the period of concern to NatureScot due to the time lag in population response as a result of the age of first breeding of the seabirds of interest (four to six years). Thus, six years was chosen as the most informative period to hindcast the additional birds that would have survived had the fishery been closed, and for the purpose of this analysis fishing data from 2017 onwards is presented.

This calculation was made for each difference in sandeel TSB from the estimate of TSB from ICES (2023) and the reported catch (Table 5). The estimated TSB from ICES (2023) is based on the predicted stock biomass on the first of January in each year, and the catch is then removed from that stock later in the spring. Using the relationship between adult survival and sandeel TSB in SA4 from the Isle of May long term study the birds survival rate for the reported TSB in Table 4and the birds survival rate for this TSB minus the catch was estimated. This difference in adult survival was used to estimate the number of additional birds that would have survived had the TSB remained at the predicted level, rather than being depleted by the catch. Note that this simple analysis does not consider other effects of reduced harvest, such as the likely increase in subsequent recruitment of sandeels due to the spawning stock biomass being less depleted – the comparison simply considers the within-year change in sandeel total stock biomass caused by the fishing take. This is, therefore, a conservative (precautionary) estimate of the gain that would accrue to seabirds as a consequence of improved adult survival alone. The benefit to seabirds in this analysis does not rely on the increase that will occur due to an increase in productivity of the key seabird species as a result of an increase in sandeel TSB.

Table 5 Predicted sandeel TSB in SA4 from 2017 to 2022 and the total catch of sandeels in SA4 (from ICES 2023).

Year	TSB (tonnes)	Catch (tonnes)
2017	306,416	18,474
2018	290,383	42,296
2019	161,211	6,651
2020	507,996	20,101
2021	295,548	53,081
2022	270,418	5,490

For each species, the number of additional birds estimated to survive in each year from 2017 to 2022 was estimated and the total number of adults across those years was summed (Table 6 to Table 9).

Table 6 Calculated additional adult kittiwakes that would have survival in each of the last six years if SA4 had been closed to sandeel fisheries.

Year	Predicted adult survival without catch	Predicted adult survival with catch	Increase in adult survival	Additional birds per annum
2017	0.8539	0.8483	0.0057	837
2018	0.8490	0.8347	0.0143	2,118
2019	0.7955	0.7917	0.0038	567
2020	0.8999	0.8962	0.0037	543
2021	0.8506	0.8326	0.0180	2,664
2022	0.8426	0.8407	0.0019	276
Total				**7,005**

Table 7 Calculated additional adult guillemots that would have survival in each of the last six years if SA4 had been closed to sandeel fisheries.

Year	Predicted adult survival without catch	Predicted adult survival with catch	Increase in adult survival	Additional birds per annum
2017	0.9115	0.9081	0.0035	1,194
2018	0.9085	0.8998	0.0088	3,022
2019	0.8758	0.8734	0.0023	809
2020	0.9397	0.9375	0.0022	775
2021	0.9095	0.8985	0.0110	3,800
2022	0.9046	0.9034	0.0011	394
Total				**9,993**

Table 8 Calculated additional adult razorbills that would have survival in each of the last six years if SA4 had been closed to sandeel fisheries.

Year	Predicted adult survival without catch	Predicted adult survival with catch	Increase in adult survival	Additional birds per annum
2017	0.9016	0.8989	0.0027	206
2018	0.8992	0.8924	0.0068	522
2019	0.8737	0.8719	0.0018	140
2020	0.9235	0.9217	0.0018	134
2021	0.9000	0.8914	0.0086	656
2022	0.8961	0.8952	0.0009	68
Total				**1,725**

Table 9 Calculated additional adult puffins that would have survival in each of the last six years if SA4 had been closed to sandeel fisheries.

Year	Predicted adult survival without catch	Predicted adult survival with catch	Increase in adult survival	Additional birds per annum
2017	0.8864	0.8802	0.0062	1,392
2018	0.8810	0.8654	0.0156	3,524
2019	0.8226	0.8184	0.0042	943
2020	0.9366	0.9326	0.0040	904
2021	0.8828	0.8631	0.0197	4,432
2022	0.8740	0.8719	0.0020	459
Total				**11,655**

The predicted annual impacts from the project across the SPAs assessed was summed and multiplied by six, to provide the total predicted impact across the period of the hindcast analysis. This was then compared to the predicted counterfactual benefit to each species SPA population had the fishery closed prior to the 2017 catch. The compensation ratio for each species SPA population was then calculated (Table 10).

Table 10 Summary of predicted annual impacts, predicted impacts across six years, predicted additional birds from sandeel fisheries closure and estimated compensation ratio.

Species	Annual predicted impact	Predicted impact across six years	Predicted benefit	Compensation ratio
Kittiwake	661	3,965	7,005	1.8
Guillemot	1,430	8,578	9,993	1.2
Razorbill	75	75	449	3.8
Puffin	33	200	9,042	45.1

The result of this analysis showed that had the fishery been closed prior to the 2017 catch the additional adult birds that would have survived in the six years until 2022 would have been sufficient to compensate for the predicted impacts from the project. The compensation ratios varied across species from 1:1.2 for guillemot to 1:45 for puffin. This variation is due to the different species-specific relationships between sandeel TSB in SA4 and adult survival on the Isle of May, as well as to differences in predicted impacts across species.

It is important to note that the assessment is precautionary for several reasons. It was assumed that only adult survival would benefit from the closure of the fishery, which in reality would have also provided a benefit to the survival of immature age classes, creating a larger pool of birds to recruit into the SPA populations. The analysis also assumes that removing the catch of sandeels would have no effect on the sandeel population in SA4. It is highly likely that the closure of the fishery would have resulted in greater recruitment of immature sandeels to the breeding population, resulting in larger sandeel populations in SA4 across the six years of the analysis. It is therefore likely that the sandeel population would have been larger than that used to estimate the benefit to adult survival and the difference in the sandeel TSB in 2017 and 2022 would likely have been larger than estimated here. Therefore, there is high confidence that if sandeel fisheries were closed now, it would be reasonable to expect this response in the seabird populations tested above.

2.4. Ten-year PVA model of Sandeel Closure

The analyses above have investigated the impact of removing the TAC for SA4 and the benefit to the relevant species of an increase in adult survival only. The purpose has been to demonstrate that this mechanism alone will provide the immediate benefit needed to offset the worst case impacts of the project. However, over the medium-term and long-term the improvements from seabird chick productivity will result in greater recruitment into the adult population, providing an additional benefit. It is also likely that the sandeel population will start to recover and the sandeel TSB will increase towards levels seen historically.

This final analysis therefore takes a more holistic view over a ten year period to demonstrate not only the benefits of an increase in adult survival, but also the benefits that will accrue from an increase in productivity.

This analysis was undertaken using the NE PVA tool. This tool was used to assess the impact of the windfarm and incorporates the delayed demographic response in the population estimates. This provides a valid estimate of the benefits because it has been completed using the same model that was used to assess the impacts.

A model was run for each species with the baseline adult survival and productivity estimated from the relationship between adult survival and productivity and sandeel TSB from the Isle of May. Impact scenarios were then entered into the tool for the impact only and net benefit based on sandeel TSB increases in 5% increments from 300,000 tonnes to 400,000 tonnes (see Table 2 for increases in adult survival and Table 11 for increases in productivity). This approach provides a predicted short term response from the seabird populations in SPAs to the relatively small potential increases in sandeel TSB that may occur across shorter timescales. Unlike the assessments above increases in productivity were included and the ten year time span allows for short term benefits beyond the age at first breeding (four to six years across the species tested) to be predicted.

Table 11 Predicted increase in productivity of all species from incremental increases in sandeel TSB in SA4.

Scenario	Sandeel TSB (tonnes)	Kittiwake		Guillemot		Puffin	
		Predicted adult survival	Increase in adult survival	Predicted adult survival	Increase in adult survival	Predicted adult survival	Increase in adult survival
Baseline	300,000	0.8384		0.7126		0.7404	
5%	315,000	0.8482	0.0098	0.7168	0.0043	0.7459	0.0055
10%	330,000	0.8576	0.0192	0.7209	0.0083	0.7511	0.0108
15%	345,000	0.8665	0.0281	0.7248	0.0122	0.7561	0.0158
20%	360,000	0.8751	0.0366	0.7285	0.0160	0.7609	0.0206
25%	375,000	0.8833	0.0449	0.7321	0.0195	0.7656	0.0252
400,000 tonnes	400,000	0.8962	0.0578	0.7378	0.0252	0.7728	0.0325

Models were run for the combined populations of the SPAs shown in Table 3, to show the overall benefit to the overall population. This was a precautionary approach, as other colonies (both in SPAs and elsewhere) that forage in SA4 are very likely to also benefit from closure of the sandeel fishery.

Models were run for kittiwake, guillemot, razorbill and puffin populations. There was no productivity benefit modelled for razorbill as there was no empirical evidence for a relationship with sandeel TSB from the Isle of May.

The predicted net benefit from closure of the sandeel fishery for each species was estimated at projected year ten (Table 12). There are several advantages to assessing the benefit at year ten. This reduces the effect of the assumption of density independence in the PVA while providing details on the short-term effects of closing the sandeel fishery in SA4. It also allows the effects of the increase in productivity to benefit the population through increased immature population size available to recruit from the age at first breeding (four years for kittiwake, six years for guillemot and razorbill and five years for puffin).

Table 12 PVA estimated net benefit (additional adult birds) at 10 years from increases in Adult Survival and Productivity

Species	Total SPA Population size	Net Benefit (5%)	Net Benefit (10%)	Net Benefit (15%)	Net Benefit (20%)	Net Benefit (25%)	Net Benefit 400,000 t TSB
Kittiwake	148,026	16,918	33,963	51,294	68,743	86,370	116,174
Guillemot	344,608	15,134	29,343	41,053	51,838	61,999	77,832
Razorbill*	76,366	2,861	5,726	8,443	11,066	13,675	17,849
Puffin	174,744	17,648	35,208	52,721	70,030	87,255	115,417

* Note that estimates for razorbill are for survival increases only

The table above shows the net benefit to the SPA populations of the key species from five scenarios where the sandeel TSB increases in 5% increments from a baseline of 300,000 tonnes, and one scenario where the sandeel TSB increases to 400,000 tonnes, after ten years. This analysis includes the benefit from increases of both adult survival and productivity. Every scenario shows a substantial increase in population of the key species. For example, if sandeel TSB increases by 5% over the ten-year period then there will a benefit of 16,918 kittiwakes, 15,134 guillemots, 2,861 razorbills and 17,648 puffins.

It is likely that once fishing pressure has been removed that the sandeel population will start to recover towards levels seen historically in SA4. If the population recovers to 400,000 tonnes then this analysis shows that over ten-years there would be an additional 116,174 kittiwakes, 77,832 guillemots, 17,849 razorbills and 115,417 puffins.

These increases not only offset the impacts of the project but may also provide compensation for future projects and additional resilience to these seabird populations to pressures.

2.5. Conclusion – timing of benefits

The concern expressed by NatureScot that there may be a lag in seabird populations responses to the closure of SA4 to sandeel fishing seems reasonable when the age at first breeding is considered in isolation. It is certainly correct that the productivity benefits of sandeel fisheries closure would not occur immediately following closure of the fishery. However, the analyses in this report have demonstrated that only taking account of the sandeels that would have been taken by the fishery, the impacts from the project alone would likely be compensated for by increases in adult survival only, even at much lower changes in TSB than the 100,000 tonne increase between 300,000 and 400,000 tonnes that produces the worst-case predicted benefits considered in the Fisheries Compensatory Measures Evidence Report. For kittiwake and guillemot there would be a positive net benefit with only a 10% increase in TSB (i.e. from 300,000 to 330,000 tonnes) and for razorbill and puffin this would occur at only a 5% increase (i.e. from 300,000 to 315,000 tonnes).

Hindcast analysis showed that had the sandeel fishery in SA4 been closed prior to the 2017 catch, the number of additional adult birds predicted to survive would have been much larger for all species than the number of predicted mortalities from the project across the same period (had Berwick Bank been

constructed in 2017). There is therefore no need to even rely on the productivity benefits that may take up to six years to be realised.

Finally, population modelling across a ten year period using the NE PVA tool accounted for the delayed demographic response due to increases in productivity. The assessment demonstrated that closure of the Sandeel fisheries would offset the impacts of Berwick Bank and provide further benefit that could be used to offset future projects and/or provide further resilience for seabird populations.

All these assessments included several important elements which ensure they are suitably precautionary:

- Only the benefits to adult survival were assumed in the assessment of annual benefit and the hindcast analysis;
- The benefit to immature seabird survival was not considered and would also be likely to increase resulting in greater recruitment from the first year of the closure of the fishery;
- Conservative increases in sandeel TSB in increments between 300,000 tonnes and 400,000 tonnes were used to calculate the annual benefits and the ten-year PVA, the realistic worst-case benefit scenario;
- The most precautionary impact assessment (Scope B) was used to calculate net benefit.;
- Only the removal of catch was assumed to increase sandeel TSB. Any increase in recruitment leading to higher sandeel TSB was not considered; and
- The benefit to seabirds in colonies outside SPAs was not considered.

These analyses, combined with the precautionary approach taken to assessment, show that the concerns of NatureScot about a delay to seabird population response to sandeel fisheries closure and estimates of annual benefit can be allayed. It is clear that in the short term that the likely response of populations to relatively small increases sandeel TSB is sufficient to compensate for the most precautionary predicted impact of the project. Much greater benefits to seabird populations can be expected over a longer time period from productivity increases and as Sandeel TSB recovers.